Part I

3

Disturbance Affecting Stream Corridors

3.A Natural Disturbances
3.B Human-Induced Disturbances

*Disturbances that bring changes to stream corridors and associated ecosystems are natural events or human-induced activities that occur separately or simultaneously (**Figure 3.1**). Either individually or in combination, disturbances place stresses on the stream corridor that have the potential to alter its structure and impair its ability to perform key ecological functions. The true impact of these disturbances can best be understood by how they affect the ecosystem structure, processes, and functions introduced in Chapters 1 and 2.*

*A disturbance occurring within or adjacent to a corridor typically produces a causal chain of effects, which may permanently alter one or more characteristics of a stable system. A view of this chain is illustrated in **Figure 3.2** (Wesche 1985). This view can be applied in many stream corridor restoration initiatives with the ideal goal of moving back as far as feasible on the cause-effect chain to plan and select restoration alternatives (Armour and Williamson 1988). Otherwise, chosen alternatives may merely treat symptoms rather than the source of the problem.*

Figure 3.1: Disturbance in the stream corridor.
Both natural and human-induced disturbances result in changes to stream corridors.

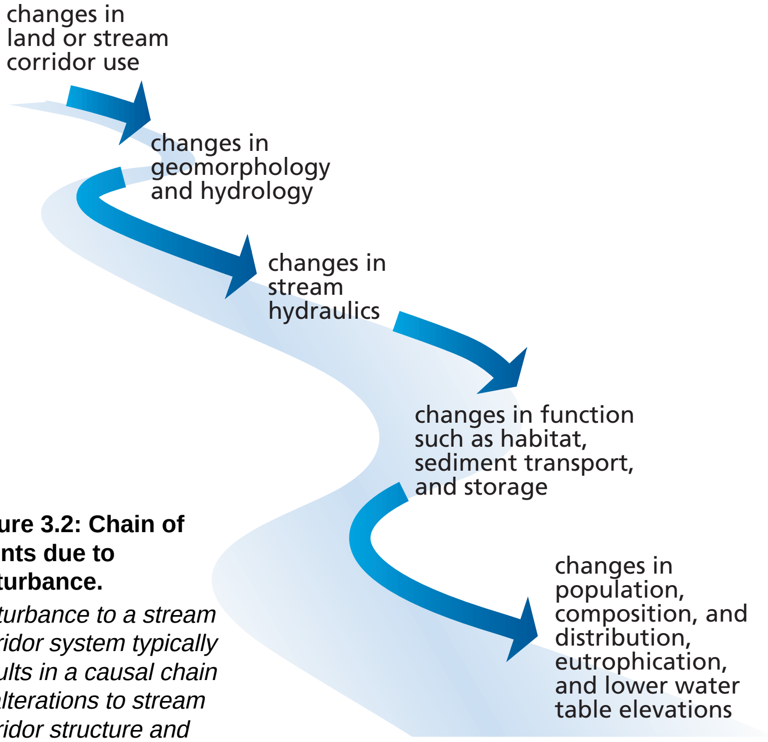


Figure 3.2: Chain of events due to disturbance. *Disturbance to a stream corridor system typically results in a causal chain of alterations to stream corridor structure and functions.*

Using this broad goal along with the thoughtful use of a responsive evaluation and design process will greatly reduce the need for trial-and-error experiences and enhance the opportunities for successful restoration. Passive restoration, as the critical first option to pursue, will result.

Disturbances can occur anywhere within the stream corridor and associated ecosystems and can vary in terms of frequency, duration, and intensity. A single disturbance event may trigger a variety of disturbances that differ in frequency, duration, intensity, and location. Each of these subsequent forms of direct or indirect disturbance should be addressed in restoration planning and design for successful results.

This chapter focuses on understanding how various disturbances affect the stream corridor and associated ecosystems. We can better determine what actions are needed to restore stream corridor structure and functions by understanding the evolution of what disturbances are stressing the system, and how the system responds to those stresses.

Section 3.A: Natural Disturbances

This section introduces natural disturbances as a multitude of potential events that cover a broad range of temporal and spatial scales. Often the agents of natural regeneration and restoration, natural disturbances are presented briefly as part of the dynamic system and evolutionary process at work in stream corridors.

Section 3.B: Human-Induced Disturbances

Traditionally the use and management of stream corridors have focused on the health and safety or material wealth of society. Human-induced forms of disturbances and resulting effects on the ecological structure and functions of stream corridors are, therefore, common. This section briefly describes some of these major disturbance activities and their potential effects.

Changes on Broad Temporal and Spatial Scales

Disturbance occurs within variations of scale and time. Changes brought about by land use, for example, may occur within a single year at the stream or reach scale (crop rotation), a decade within the corridor or stream scale (urbanization), and even over decades within the landscape or corridor scale (long-term forest management). Wildlife populations, such as monarch butterfly populations, may fluctuate wildly from year to year in a given locality while remaining nationally stable over several decades. Geomorphic or climatic changes may occur over hundreds to thousands of years, while weather changes daily.

Tectonics alter landscapes over periods of hundreds to millions of years, typically beyond the limits of human observance. Tectonics involves mountain-building forces like folding and faulting or earthquakes that modify the elevation of the earth's surface and change the slope of the land. In response to such changes, a stream typically will modify its cross section or its planform. Climatic changes, in contrast, have been historically and even geologically recorded. The quantity, timing, and distribution of precipitation often causes major changes in the patterns of vegetation, soils, and runoff in a landscape. Stream corridors subsequently change as runoff and sediment loads vary.

3.A Natural Disturbances

Floods, hurricanes, tornadoes, fire, lightning, volcanic eruptions, earthquakes, insects and disease, landslides, temperature extremes, and drought are among the many natural events that disturb structure and functions in the stream corridor (**Figure 3.3**). How ecosystems respond to these disturbances varies according to their relative stability, resistance, and resilience. In many instances they recover with little or no need for supplemental restoration work.

Natural disturbances are sometimes agents of regeneration and restoration. Certain species of riparian plants, for example, have adapted their life cycles to include the occurrence of destructive, high-energy disturbances, such as alternating floods and drought.

In general, riparian vegetation is resilient. A flood that destroys a mature cottonwood gallery forest also commonly creates nursery conditions necessary for the establishment of a new forest (Brady et al. 1985), thereby increasing the resilience and degree of recovery of the riparian system.

Figure 3.3: Drought—one of many types of natural disturbance. *How a stream corridor responds to disturbances depends on its relative stability, resistance, and resilience.*

Ecosystem Resilience in Eastern Upland Forests

Eastern upland forest systems, dominated by stands of beech/maple, have adapted to many types of natural disturbances by evolving attributes such as high biomass and deep, established root systems (**Figure 3.4**). Consequently, they are relatively unperturbed by drought or other natural disturbances that occur at regular intervals. Even when unexpected severe stress such as fire or insect damage occurs, the impact is usually only on a local scale and therefore insignificant in the persistence of the community as a whole.

Resilience of the Eastern Upland Forest can be disrupted, however, by widespread effects such as acid rain and indiscriminate logging and associated road building. These and other disturbances have the potential to severely alter lighting conditions, soil moisture, soil nutrients, soil temperature and other factors critical for persistence of the beech/maple forest. Recovery of an eastern "climax" system after a widespread disturbance might take more than 150 years.

Figure 3.4: Eastern upland forest system.
The beech/maple-dominated system is resistent to many natural forms of stress due to high biomass; deep, established root systems; and other adaptations.

Before the Next Flood

Recently the process of recovery from major flood events has taken on a new dimension. Environmental easements, land acquisition, and relocation of vulnerable structures have become more prominent tools to assist recovery and reduce long-term flood vulnerability. In addition to meeting the needs of disaster victims, these actions can also be effective in achieving stream corridor restoration. Local interest in and support for stream corridor restoration may be high after a large flood event, when the floodwaters recede and the extent of property damage can be fully assessed. At this point, public recognition of the costly and repetitive nature of flooding can provide the impetus needed for communities and individuals to seek better solutions. Advanced planning on a systemwide basis facilitates identification of areas most suited to levee setback, land acquisition, and relocation.

The city of Arnold, Missouri, is located about 20 miles southwest of St. Louis at the confluence of the Meramec and Mississippi Rivers. When the Mississippi River overflows its banks, the city of Arnold experiences backwater conditions—river water is forced back into the Meramec River, causing flooding along the Meramec and smaller tributaries to the Meramec. The floodplains of the Mississippi, Meramec, and local tributaries have been extensively developed. This development has decreased the natural function of the floodplain. In 1991 Arnold adopted a floodplain management plan that included, but was not limited to, a greenway to supplement the floodplain of the Mississippi River, an acquisition and relocation program to facilitate creation of the greenway, regulations to guide future development and ensure its consistency with the floodplain management objectives, and a watershed management plan. The 1993 floods devastated Arnold (**Figure 3.5**). More than $2 million was spent on federal disaster assistance to individuals, and the city's acquisition program spent $7.3 million in property buyouts. Although not as severe as the 1993 floods, the 1995 floods were the fourth largest in Arnold's history. Because of the relocation and other floodplain management efforts, federal assistance to individuals totaled less than $40,000. As the city of Arnold demonstrated, having a local floodplain management plan in place before a flood makes it easier to take advantage of the mitigation opportunities after a severe flood.

Figure 3.5: Flooding in Arnold, Missouri (1993).

Across the Midwest, the 1993 floods resulted in record losses with over 55,000 homes flooded. Total damage estimates ranged between $12 billion and $16 billion. About half of the damage was to residences, businesses, public facilities, and transportation infrastructure. The Federal Emergency Management Agency and the U.S. Department of Housing and Urban Development were able to make considerably more funding available for acquisition, relocation, and raising the elevation of properties than had been available in the past. The U.S. Fish and Wildlife Service and state agencies were also able to acquire property easements along the rivers. As a result, losses from the 1995 floods in the same areas were reduced and the avoided losses will continue into the future. In addition to reducing the potential for future flood damages, the acquisition of property in floodplains and the subsequent conversion of that property into open space provides an opportunity for the return of the natural functions of stream corridors.

3.B Human-Induced Disturbances

Human-induced disturbances brought about by land use activities undoubtedly have the greatest potential for introducing enduring changes to the ecological structure and functions of stream corridors.

Human-induced disturbances brought about by land use activities undoubtedly have the greatest potential for introducing enduring changes to the ecological structure and functions of stream corridors (**Figure 3.6**). Chemically defined disturbance effects, for example, can be introduced through many activities including agriculture (pesticides and nutrients), urban activities (municipal and industrial waste contaminants), and mining (acid mine drainage and heavy metals).

Figure 3.6: Agricultural activity.
Land use activities can cause extensive physical, biological, or chemical disturbances in a watershed and stream corridor.

They have the potential to disturb natural chemical cycles in streams, and thus to degrade water quality. Chemical disturbances from agriculture are usually widespread, nonpoint sources. Municipal and industrial waste contaminants are typically point sources and often chronic in duration. Secondary effects, such as agricultural chemicals attached to sediments and increased soil salinity, frequently occur as a result of physical activities (irrigation or heavy application of herbicide). In these cases, it is better to control the physical activity at its source than to treat the symptoms within a stream corridor.

Biologically defined disturbance effects occur within species (competition, cannibalism, etc.) and among species (competition, predation, etc.). These are natural interactions that are important determinants of population size and community organization in many ecosystems. Biological disturbances due to improper grazing management or recreational activities are frequently encountered. The introduction of exotic flora and fauna species can introduce widespread, intense, and continuous stress on native biological communities.

Physical disturbance effects occur at any scale from landscape and stream corridor to stream and reach, where they can cause impacts locally or at locations far removed from the site of origin. Activities such as flood control, forest management, road building and maintenance, agricultural tillage, and irrigation, as well as urban encroachment, can have dramatic effects on the geomorphology and hydrology of a watershed and the stream corridor morphology within it. By altering the structure of plant communities and soils, these and other activities can affect the infiltration and movement of water, thereby altering the timing and magnitude of runoff events. These disturbances also occur at the reach scale and cause changes that can be addressed in stream corridor restoration. The modification of stream hydraulics, for example, directly affects the system, causing an increase in the intensity of disturbances caused by floods.

This section is divided into two subsections. Common disturbances are discussed first, followed by land use activities.

Common Disturbances

Dams, channelization, and the introduction of exotic species represent forms of disturbance found in many if not all of the land uses discussed later in this chapter. Therefore, they are presented as separate discussions in advance of more specific land use activities that potentially introduce disturbance. Many societal benefits are derived from these land use changes. This document, however, focuses on their potential for disturbance and subsequent restoration of stream corridors.

Dams

Ranging from small temporary structures constructed of stream sediment to huge multipurpose structures, dams can have profound and varying impacts on stream corridors (**Figure 3.7**). The extent and impact largely depend on the purposes of the dam and its size in relation to stream flow.

Changes in discharges from dams can cause downstream effects. Hydropower dam discharges may vary widely on a hourly and daily basis in response to peaking power needs and affect the downstream morphology. The rate of change in the discharge can be a significant factor increasing streambank erosion and subsequent loss of riparian habitat. Dams release water that differs from that received. Flowing streams can slow and change into slack water pools, sometimes becoming lacustrine environments. A water supply dam can decrease instream flows, which alters the stream corridor morphology, plant communities and habitat or can augment flows, which also results in alterations to the stream corridor.

Figure 3.7: An impoundment dam
Dams range widely in size and purpose, and in their effects on stream corridors.

Dams affect resident and migratory organisms in stream channels. The disruption of flow blocks or slows the passage and migration of aquatic organisms, which in turn affects food chains associated with stream corridor functions (**Figure 3.8**). Without high flows, silt is not washed from the gravel beds on which many aquatic species rely for spawning. Upstream fish movement may be blocked by relatively small structures. Downstream movement may be slowed or stopped by the dam or its reservoir. As a stream current dissipates in a reservoir, smolts of anadromous fish may lose a sense of downstream direction or might be subject to more predation, altered water chemistry, and other effects.

Dams also affect species by altering water quality. Relatively constant flows can create constant temperatures, which affect those species dependent on temperature variations for reproduction or maturation. In places where irrigation water is stored, unnaturally low flows can occur and warm more easily and hold less oxygen which can cause stress or death in aquatic organisms. Likewise, large storage pools keep water cool and released water can result in significantly cooler temperatures downstream to which native fish might not be adapted.

Figure 3.8: Biological effects of dams.
Dams can prevent the migration of anadromous fish and other aquatic organisms.

Dams also disrupt the flow of sediment and organic materials (Ward and Standford 1979). This is particularly evident with the largest dams, whereas dams which are typically low in elevation and have small pools modify natural flood and transport cycles only slightly. As stream flow slackens, the load of suspended sediment decreases and sediment drops out of the stream to the reservoir bottom. Organic material suspended in the sediment, which provides vital nutrients for downstream food webs, also drops out and is lost to the stream ecosystem.

When suspended sediment load is decreased, scouring of the downstream streambed and banks may occur until the equilibrium bed load is reestablished. Scouring lowers the streambed and erodes streambanks and riparian zones, vital habitat for many species. Without new sources of sediment, sandbars alongside and within streams are eventually lost, along with the habitats and species they support. Additionally, as the stream channel becomes incised, the water table underlying the riparian zone also lowers. Thus, channel incision can lead to adverse changes in the composition of vegetative communities within the stream corridor.

Conversely, when dams are constructed and operated to reduce flood damages, the lack of large flood events can result in channel aggradation and the narrowing and infilling of secondary channels (Collier et al. 1996).

The Glen Canyon Dam Spiked Flow Experiment

The Colorado River watershed is a 242,000-square-mile mosaic of mountains, deserts, and canyons. The watershed begins at over 14,000 feet in the Rocky Mountains and ends at the Sea of Cortez. It supports a unique assemblage of fish and plants. Many of these native species require very specific environments and ecosystem processes to survive. Before settlement of the Colorado River watershed, the basin's rivers and streams were characterized by a large stochastic variability in the annual and seasonal flow levels. This was representative of the highly variable levels of moisture and runoff. This hydrologic variability was a key factor in the evolution of the basin's ecosystems.

Settlement and subsequent development and management of the waters of the Colorado River system detrimentally affected the ecological processes and natural species that maintain ecosystem health and biodiversity. Today over 40 dams and diversion structures control the river system and result in extensive fragmentation of the watershed and riverine ecosystem. Watershed development, in addition to the dams, has also resulted in modifications to the hydrology and the sediment input.

Historically, flood flows moved nutrients into the ecosystem, carved the canyons, and redistributed sand from the river bottom creating sandbars and backwaters where fish could breed and grow. In 1963, the closure of Glen Canyon Dam about 15 miles upstream of the Grand Canyon, permanently altered these processes and initiated ecological decline downstream (**Figure 3.9**). In the spring of 1996 the Bureau of Reclamation ran the first controlled release of water from Glen Canyon Dam to test and study the ability to use "spike flows" for redistribution of sediment (sand) from the river bottom to the river's margins in eddy zones. The primary objective of the controlled release of large flows was to restore portions of the ecological equation by mimicking the annual floods which used to occur in the Grand Canyon.

Flow releases of 45,000 cfs were maintained for one week. Formal reports from a variety of scientists are only now being published. The results are mixed. The flood heightened and slightly widened existing sandbars. It built scores of new camping beaches and provided additional protection for archeological sites threatened with loss from erosion. The spike flow also liberated large quantities of vital nutrients. It created 20 percent more backwater areas for spawning native fish. No endangered species were significantly harmed, nor was the trout fishery immediately below Glen Canyon Dam harmed. The flow was not, however, strong enough to flush some nonnative species (e.g., tamarisk) from the system as had been hoped. One important finding was that most of the ecological effects were realized during the first 48 hours of the week-long high-flow conditions.

Figure 3.9: Glen Canyon Dam.
The Glen Canyon Dam permanently altered downstream functions and ecology.

The Bureau of Reclamation is continuing to monitor the effects of the spike flow. The effects of the restorative flood are not permanent. New beaches and sandbars will continue to erode. An adaptive management approach will help guide future decisions about spike flows and management of flows to better balance the competing needs for hydropower, flood protection, and preservation of the Grand Canyon ecosystem. It might be that short spike flows are an ecologically more acceptable means to dispose of heavy spring runoff than the traditional steady, somewhat heightened flows. While the results are mixed, it is clear that changing flow releases provides another tool that, if properly used, can help restore ecological processes that are essential for maintaining ecosystem health and biodiversity.

Flood damage reduction measures encompass a wide variety of strategies, some of which might not be compatible with goals of stream corridor restoration.

Channelization and Diversions

Like dams, channelization and diversions cause changes to stream corridors. Stream channelization and diversions can disrupt riffle and pool complexes needed at different times in the life cycle of certain aquatic organisms. The flood conveyance benefits of channelization and diversions are often offset by ecological losses resulting from increased stream velocities and reduced habitat diversity. Instream modifications such as uniform cross section and armoring result in less habitat for organisms living in or on stream sediments (**Figure 3.10**). Habitat is also lost when large woody debris, which frequently supports a high density of aquatic macroinvertebrates, is removed (Bisson et al. 1987, Sweeney 1992).

The impacts of diversions on the stream corridor depend on the timing and amount of water diverted, as well as the location, design, and operation of the diversion structure or its pumps (**Figure 3.11**). The effects of diversions on stream flows are similar to those addressed for dams. The effects of levees depend on siting considerations, design, and maintenance practices.

Earthen diversion channels leak and the water lost for irrigation may create wetlands. Leakage may support a vegetative corridor approaching that of a simple riparian community, or it can facilitate spread of exotic species, such as tamarisk (*Tamarisk chinensis*). Diversions can also trap fish resulting in diminished spawning, lowered health of species, and death of fish.

Flood damage reduction measures encompass a wide variety of strategies, some of which might not be compatible with goals of stream corridor restoration. Floodwalls and levees can increase the velocity of the stream and elevate flood heights by constraining high flows of the river to a narrow band. When floodwalls are set farther back from streams, they can define the stream corridor and for some or all of the natural functions of the floodplain, including temporary flood storage.

Levees juxtaposed to streams tend to replace riparian vegetation. The loss or diminishment of the tree overstory and other riparian vegetation results in the changes in shading, temperature, and nutrients discussed earlier.

Figure 3.10: Stream channelization.
Instream modifications, such as uniform cross section and armoring, result in ecological decline.

Introduction of Exotic Species

Stream corridors naturally evolve in an environment of fluctuating flows and seasonal rhythms. Native species adapted to such conditions might not survive without them. For stream corridors that have naturally evolved in an environment of spring floods and low winter and summer flows, the diminution of such patterns can result in the creation of a new succession of plants and animals and the decline of native species. In the West, nonnative species like tamarisk can invade altered stream corridors and result in creation of a habitat with lower stability. The native fauna might not secure the same survival benefits from this altered condition because they did not evolve with tamarisk and are not adapted to using it.

The introduction of exotic species, whether intentional or not, can cause disruptions such as predation, hybridization, and the introduction of diseases. Nonnative species compete with native species for moisture, nutrients, sunlight, and space and can adversely influence establishment rates for new plantings, foods, and habitat. In some cases, exotic plant species can even detract from the recreational value of streams by creating a dense, impenetrable thicket along the streambank. Well-known examples of the effects of exotic species introduction include the planned introduction of kudzu and the inadvertent introduction of the zebra mussel. Both species have imposed widespread, intense, and continuous stress on native biological communities. Tamarisk (also known as salt cedar) is perhaps the most renowned exotic in North America. It is an aggressive, exotic colonizer in the West due to its high rate of seed production and ability to withstand long periods of inundation.

Figure 3.11: Stream diversion.
Diversions are built to provide water for numerous purposes, including agriculture, industry, and drinking water supplies.

Exotic Species in the West

Exotic animals are a common problem in many areas of the West. “Wild” burros wander up and down many desert washes and stream corridors. Their destructive foraging is often evident in sensitive riparian areas. Additionally, species such as bullfrogs, not native to most of the West, have been introduced in many waters **(Figure 3.12)**. Without the normal checks and balances found in their native habitat in the eastern United States, bullfrogs reproduce prodigiously and prey on numerous native amphibians, reptiles, fish, and small mammals.

Figure 3.12: Bullfrog
Without the normal checks and balances found in the eastern United States, bullfrogs in the West have reproduced prodigiously.
Source: C. Zabawa

Salt Cedar Control at Bosque del Apache National Wildlife Refuge, New Mexico

The exotic salt cedar (*Tamarix chinensis*) has become the predominant woody species along many of the stream corridors in the Southwest. The wide distribution of this species can be attributed to its ability to tolerate a wide range of environmental factors and its adaptability to new stream conditions accelerated by human activities (e.g., summer flooding or no flooding, reduced or altered water tables, high salinity from agricultural tail water, and high levels of sediment downstream from grazed watersheds). Salt cedar is particularly abundant on regulated rivers. Its ability to rapidly dominate riparian habitat results in exclusion of cottonwood, willow, and many other native riparian species.

Salt cedar control is an integral part of riparian restoration and enhancement at Bosque del Apache National Wildlife Refuge on the Rio Grande in central New Mexico. Diverse mosaics of native cottonwood/ black willow (*Populus fremontii/Salix nigra*) forests, screw bean mesquite (*Prosobis pubescens*) brushlands, and saltgrass (*Distichlis* sp.) meadows have been affected by this invasive exotic. The degree of infestation varies widely throughout the refuge, ranging from isolated plants to extensive monocultures totaling thousands of acres. For the past 10 years, the refuge has experimented with mechanical and herbicide programs for feasible control of salt cedar.

Figure 3.13: Salt cedar site *(a)* before and *(b)* after treatment.
Combinations of burning, chemical treatment, and mechanical control techniques can be used to control salt cedar, giving native vegetation an opportunity to colonize and establish.

(a)

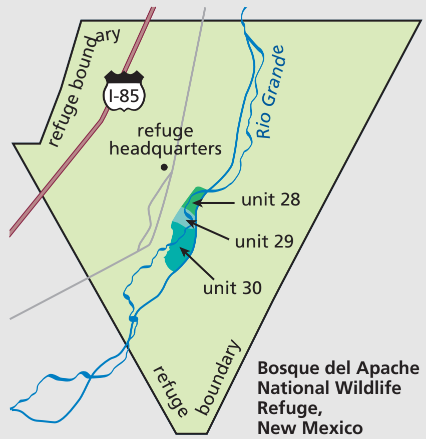
(b)

The refuge has experimented with several techniques in controlling large salt cedar monocultures prior to native plant establishment. Herbicide/ broadcast burn and mechanical techniques have been employed on three 150-acre units on the refuge (**Figure 3.13**). Initially, the strategy for control was aerial application of a low-toxicity herbicide, at 2 quarts/acre in the late summer, followed by a broadcast prescribed burn a year later. This control method appeared effective; however, extensive resprouting following the burn indicated the herbicide might not have had time to kill the plant prior to the burning.

Mechanical control using heavy equipment was another option. Root plowing and raking have long been used as a technique for salt cedar control. A plow is pulled by a bulldozer, severing salt cedar root crowns from the remaining root mass about 12 to 18 inches below the ground surface, followed by root raking, which pulls the root crowns from the ground for later stacking.

There are advantages and disadvantages with each technique (**Table 3.1**). Cost-effectiveness is the distinct advantage of an herbicide/burn control program. Costs can be low if resprouting is minor and burning removes much of the aerial vegetation. Because an herbicide/burn program is potentially cost-effective, this technique is again being experimented with at the refuge. Costs are being further reduced by combining the original herbicide with a less expensive herbicide. A delay of 2 years prior to broadcast burning is expected to dramatically reduce resprouting, allowing time for the herbicide to effectively move throughout the entire plant. Disadvantages of herbicide application include restrictions regarding application near water bodies and impacts on native vegetation remnants within salt cedar monocultures.

Advantages of mechanical control include proven effectiveness and more thorough site preparation for revegetation. Disadvantages include significant site disturbance, equipment breakdowns/delays, and lower effectiveness in tighter clay soils. Both methods require skill in equipment operation whether applying herbicide aerially or operating heavy equipment.



Other salt cedar infestations on the refuge are relatively minor, consisting of small groups of plants or scattered individual plants. Nonetheless, these patches are aggressively controlled to prevent spread. Heavy equipment requires working space and is generally restricted to sites of 1 acre and larger. For these smaller areas, front end loaders have been filled with “stinger bars,” which remove individual plant root crowns much like a root plow. For areas of less than 1 acre, spot herbicide applications are made using a 1 percent solution from a small sprayer. To date, approximately 1,000 acres of salt cedar have been controlled, with over 500 acres effectively restored to native riparian vegetative communities. A combination of techniques in the control of salt cedar has proven effective and will continue to be used in the future.

Table 3.1: Salt cedar control techniques at Bosque del Apache.

Unit	Herbicide	Broadcast Burn	Root Plow	Root Rake	Pile Burn	% Control
28	x	x	x			88%
29	x	x	x	x	x	90%
30			x	x	x	99%

Land Use Activities

Agriculture

According to the 1992 Natural Resources Inventory (USDA-NRCS 1992), cultivated and noncultivated cropland make up approximately 382 million acres of the roughly 1.9 billion acres existing in the contiguous United States, Hawaii, Puerto Rico, and the U.S. Virgin Islands (excludes Alaska). The conversion of undisturbed land to agricultural production has often disrupted the previously existing state of dynamic equilibrium. Introduced at the landscape, watershed, stream corridor, stream, and reach scales, agricultural activities have generally resulted in encroachment on stream corridors with significant changes to the structure and mix of functions usually found in stable systems (**Figure 3.14**).

Vegetative Clearing

One of the most obvious disturbances from agriculture involves the removal of native, riparian, and upland vegetation. Producers often crop as much productive land as possible to enhance economic returns; therefore, vegetation is sacrificed to increase arable acres.

As the composition and distribution of vegetation are altered, the interactions between structure and function become fragmented. Vegetative removal from streambanks, floodplains, and uplands often conflicts with the hydrologic and geomorphic functions of stream corridors. These disturbances can result in sheet and rill as well as gully erosion, reduced infiltration, increased upland surface runoff and transport of contaminants, increased streambank erosion, unstable stream channels, and impaired habitat.

Instream Modifications

Flood-control structures and channel modifications implemented to protect agricultural systems further disrupt the geomorphic and hydrologic characteristics of stream corridors and associ-

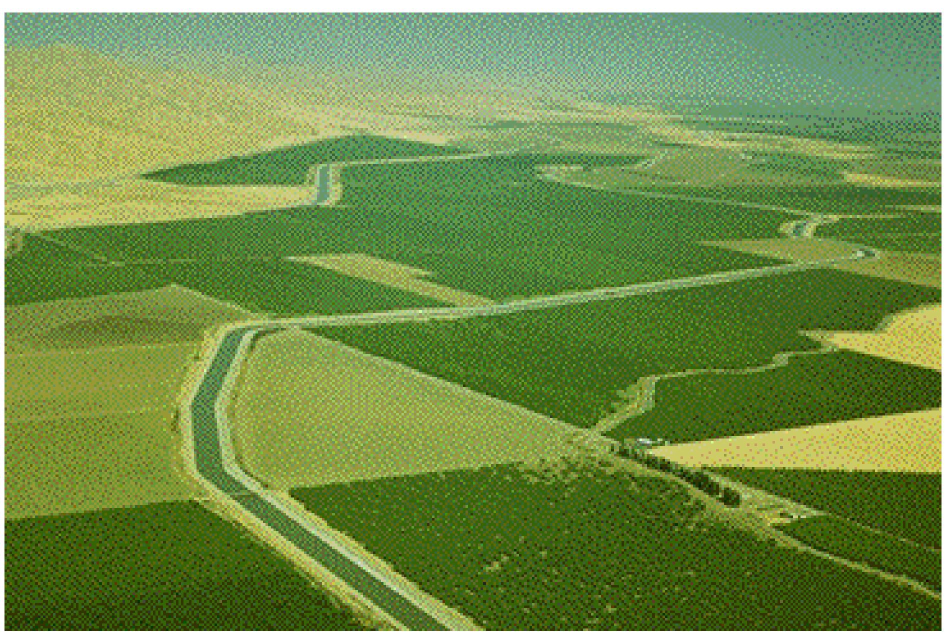


Figure 3.14: Agriculture fragments natural ecosystems.
Cultivated and noncultivated cropland make up approximately 382 million acres of the roughly 1.9 billion acres existing in the contiguous United States, Hawaii, Puerto Rico, and the U.S. Virgin Islands (excludes Alaska).

ated uplands. For agricultural purposes, streams are often straightened or moved to “square-up” fields for more efficient production and reconstructed to a new profile and geometric cross section to accommodate increased runoff. Stream corridors are also often modified to enhance conditions for single purposes such as fish habitat, or to manage conditions such as localized streambank erosion. Some of the potential effects caused by these changes are impaired upland or floodplain surface and subsurface flow; increased water temperature, turbidity, and pH; incised channels; lower ground water elevations; streambank failure; and loss of habitat for aquatic and terrestrial species.

Soil Exposure and Compaction

Tillage and soil compaction interfere with soil’s capacity to partition and regulate the flow of water in the landscape, increase surface runoff, and decrease the water-holding capacity of soils. Increases in the rate and volume of throughflow in the upper soil layers are frequent. Tillage also often aids in the development of a *hard pan*, a layer of increased soil density and decreased permeability that restricts the movement of water into the subsurface.

The resulting changes in surface and ground water flow often initiate incised channels and effects similar to those discussed previously for in-stream modifications.

Irrigation and Drainage

Diverting surface water for irrigation and depleting aquifers have brought about major changes in stream corridors. Aquifers have been a desired source of water for agriculture because ground water is usually high-quality and historically abundant and is a more reliable source than rivers, lakes, and reservoirs (**Figure 3.15**). Underground water supplies have diminished at an alarming rate in the United States, with ground water levels reported to be dropping an estimated foot or more a year under 45 percent

Figure 3.15: Central pivot irrigation systems use ground water sources.
Reliance on aquifers for irrigation have brought about major changes in ground water supply, as well as the landscape.

of the ground water-irrigated cropland (Dickason 1988).

Agricultural drainage, which allows the conversion of wetland soils to agricultural production, lowers the water table. Tile drainage systems concentrate ground water discharge to a point source, in contrast to a diffuse source of seeps and springs in more natural discharges. Subsurface tile drainage systems, constructed waterways, and drainage ditches constitute a landscape scale network of disturbances. These practices have eliminated or fragmented habitat and natural filtration systems needed to slow and purify runoff. The results are often a compressed and exaggerated hydrograph.

Sediment and Contaminants

Disturbance of soil associated with agriculture generates runoff polluted with sediment, a major nonpoint source pollutant in the nation. Pesticides and nutrients (mainly nitrogen, phosphorous, and potassium) applied during the growing season can leach into ground water or flow in surface water to stream corridors, either dissolved or adsorbed to soil particles. Applied aerially, these same chemicals can drift into the stream corridor. Improper storage and application of animal waste from concentrated animal production facilities are potential sources of chemical and bacterial contaminants to stream corridors.

Soil salinity is a naturally occurring phenomenon found most often in floodplains and other low-lying areas of wet soils, lakes, or shallow water tables. Dissolved salts in surface and ground water entering these areas become concentrated in the shallow ground water and the soils as evapotranspiration removes water. Agricultural activities in such landscapes can increase the rate of soil salinization by changing vegetation patterns or by applying irrigation water without adequate drainage. In the arid and semiarid areas of the West, irrigation can import salts into a drainage basin. Since crops do not use up the salts, they accumulate in the soil. Salinity levels greater than 4 millimhos/cm can alter soil structure, promote waterlogging, cause salt toxicity in plants, and decrease the ability of plants to take up water.

Drainage and Streambank Erosion

Many wetlands have been drained to increase the acres of arable land. The drainage area of the Blue Earth River in the glaciated areas of west-central Minnesota, for example, has almost doubled due to extensive tile drainage of depressional areas that formerly stored surface runoff. Studies to identify sources of sediment in this watershed have been made, and as a result, farmers have complied with reduced tillage and increased crop residue recommendations to help decrease the suspended sediment load in the river. Testing, however, indicates the sediment problem has not been solved. Some individuals have suggested that streambank erosion, not erosion on agricultural lands, might be the source of the sediment. Streambank erosion is more likely to be the result of drainage and subsequent changes to runoff patterns in the watershed.

Forestry

Three general activities associated with forestry operations can affect stream corridors—tree removal, activities necessary to transport the harvested timber, and preparation of the harvest site for regeneration.

Removal of Trees

Forest thinning includes the removal of either mature trees or immature trees to provide more growth capability for the remaining trees. Final harvest removes mature trees, either singularly or in groups. Both activities reduce vegetative cover.

Tree removal decreases the quantity of nutrients in the watershed since approximately one-half of the nutrients in trees are in the trunks. Instream nutrient levels can increase if large limbs fall into streams during harvesting and decompose. Conversely, when tree cover is removed, there is a short-term increase in nutrient release followed by long-term reduction in nutrient levels.

Removal of trees can affect the quality, quantity, and timing of stream flows for the same reasons that vegetative clearing for agriculture does. If trees are removed from a large portion of a watershed, flow quantity can increase accordingly. The overall effect depends on the quantity of trees removed and their proximity to the stream corridor (**Figure 3.16**). Increases in flood peaks can occur if vegetation in the area closest to the stream is removed. Long-term loss of riparian vegetation can result in bank erosion and channel widening, increasing the width/depth ratio (Hartman et al. 1987, Oliver and Hinckley 1987, Shields et al. 1994). Water temperature can increase during summer and decrease in winter by removal of shade trees in riparian areas. Allowing large limbs to fall into a stream and divert stream flow may alter flow patterns and cause bank or bed erosion.

Figure 3.16: Riparian forest.
Streamside forest cover serves many important functions such as stabilizing streambanks and moderating diurnal stream temperatures.

Removal of trees can reduce availability of cavities for wildlife use and otherwise alter biological systems, particularly if a large percentage of the tree cover is removed. Loss of habitat for fish, invertebrates, aquatic mammals, amphibians, birds, and reptiles can occur.

Transportation of Products

Forest roads are constructed to move loaded logs from the landing to higher-quality roads and then to a manufacturing facility. Mechanical means to move logs to a loading area (landing) produce “skid trails.” Stream crossings are necessary along some skid trails and most forest road systems and are especially sensitive areas.

Removal of topsoil, soil compaction, and disturbance by equipment and log skidding can result in long-term loss of productivity, decreased porosity, decreased soil infiltration, and increased runoff and erosion. Spills of petroleum products can contaminate soils. Trails, roads, and landings can intercept ground water flow and cause it to become surface runoff.

Soil disturbance by logging equipment can have direct physical impact on habitat for a wide variety of amphibians, mammals, fish, birds, and reptiles, as well as physically harm wildlife. Loss of cover, food, and other needs can be critical. Sediment can clog fish habitat, widen streams, and accelerate streambank erosion.

Site Preparation

Preparing the harvested area for the next generation of desired trees typically includes some use of prescribed fire or other methods to prepare a seed bed and reduce competition from unwanted species.

Mechanical methods that completely remove competing species can cause severe compaction, particularly in wet soils. This compaction reduces infiltration and increases runoff and erosion. Moving logging debris into piles or windrows can remove important nutrients from the soil. Depending on the methods used, significant soil can be removed from the site and stacked with piled debris, further reducing site productivity.

Intense prescribed fire can volatilize important nutrients, while less intense fire can mobilize nutrients for rapid plant uptake and growth. Use of fire can also release nutrients to the stream in unacceptable quantities.

Mechanical methods that cause significant compaction or decrease infiltration can increase runoff and therefore the amount of water entering the stream system. Severe mechanical disturbance can result in significant erosion and sedimentation. Conversely, less disruptive mechanical means can increase organic matter in the soil surface and increase infiltration. Each method has advantages and disadvantages.

Direct harm can occur to wildlife by mechanical means or fire. Loss of habitat can occur if site preparation physically removes most competing vegetation. Loss of diversity can result from efforts to strongly limit competition with desired timber species. Careless use of mechanical equipment can directly damage streambanks and cause erosion.

Domestic Livestock Grazing

Grazing of domestic livestock, primarily cattle and sheep, is commonplace across the nation. Stream corridors are particularly attractive to livestock for many reasons. They are generally highly productive, providing ample forage. Water is close at hand, shade is available to cool the area, and slopes are gentle, generally less than 35 percent in most areas. Unless carefully managed, livestock can overuse these areas and cause significant disturbance (**Figure 3.17**). For purposes of the following discussion, cattle grazing provides the focus, although sheep, goats, and other less common species also can have particular effects that might be different from those discussed. It is important to note that the effects discussed result from poorly managed grazing systems.

The primary impacts that result from grazing of domestic livestock are the loss of vegetative cover due to its consumption or trampling and streambank erosion from the presence of livestock (**Table 3.2**).

Figure 3.17: Livestock in stream. *Use of stream corridors by domestic livestock can result in extensive physical disturbance and bacteriological contamination.*

Loss of Vegetative Cover

Reduced vegetative cover can increase soil compaction and decrease the depth of and productivity of topsoil. Reduced cover of mid-story and overstory plants decreases shade and increases water temperatures, although this effect diminishes as stream width increases. Sediment from upland or streambank erosion can reduce water quality through increases in turbidity and attached chemicals. Where animal concentrations are large, fecal material can increase nutrient loads above standards and introduce bacteria and pathogens, although this is uncommon. Dissolved oxygen reductions can result from high temperature and nutrient-rich waters.

Table 3.2: Livestock impacts on stream corridors.

Impact
Decreased plant vigor
Decreased biomass
Alteration of species composition and diversity
Reduction or elimination of woody species
Elevated surface runoff
Erosion and sediment delivery to streams
Streambank erosion and failure
Channel instability
Increased width to depth ratios
Degradation of aquatic species
Water quality degradation

References: Ames (1977); Knopf and Cannon (1982); Hansen et al. (1995); Kauffman and Kreuger (1984); Brooks et al. (1991); Platts (1979); MacDonald et al. (1991).

Extensive loss of ground cover in the watershed and stream corridor can decrease infiltration and increase runoff, leading to higher flood peaks and additional runoff volume. Where reduced cover increases overland flow and prevents infiltration, additional water may flow more rapidly into stream channels so that flow peaks come earlier rather than later in the runoff cycle, producing a more "flashy" stream system. Reductions in baseflow and increases in stormflow can result in a formerly perennial stream becoming intermittent or ephemeral.

Increased sedimentation of channels can reduce channel capacity, increasing width/depth ratios, forcing water into streambanks, and inducing bank erosion. This leads to channel instability, causing other adjustments in the system. Similarly, excessive water reaching the system without additional sediment may cause channel degradation as increased stream energy erodes channel bottoms, incising the channel.

Physical Impacts from Livestock Presence

Trampling, trailing, and similar activities of livestock physically impact stream corridors. Impacts on soils are particularly dependent on soil moisture content, with compaction presenting a major concern. Effects vary markedly by soil type and moisture content. Very dry soils are seldom affected, while very wet soils may also be resistant to compaction. Moist soils are typically more subject to compaction damage. Very wet soils may be easily displaced, however. Adjusting grazing use to periods where soil moisture will minimize impacts will prevent many problems.

Compaction of soils by grazing animals can cause increased soil bulk density, reduced infiltration, and increased runoff. Loss of capillarity reduces the ability of water to move vertically and laterally in the soil profile. Reduced soil moisture content can reduce site capacity for riparian-dependent plant species and favor drier upland species.

Trailing can break down streambanks, causing bank failure and increasing sedimentation. Excessive trailing can result in gully formation and eventual channel extension and migration.

Unmanaged grazing can significantly change stream geomorphology. Bank instability and increased sedimentation can cause channel widening and increases in the width/depth ratio. Increased meandering may result, causing further instability. Erosion of fine materials into the system can change channel bottom composition and alter sediment transport relationships.

Excessive livestock use can cause breakage or other physical damage to streamside vegetation. Loss of bank-holding species and undercut banks can reduce habitat for fish and other aquatic species. Excessive sedimentation can result in filling of stream gravels with fine sediments, reducing the survival of some fish eggs and newly-hatched fish due to lack of oxygen. Excessive stream temperatures can be detrimental to many critical fish species, as well as amphibians. Loss of preferred cover reduces habitat for riparian-dependent species, particularly birds.

Mining

Exploration, extraction, processing, and transportation of coal, minerals, sand and gravel, and other materials has had and continues to have a profound effect on stream corridors across the nation (**Figure 3.18**). Both surface mining and subsurface mining damage stream corridors. Surface mining methods include strip mining, open-pit operations, dredging, placer mining, and hydraulic mining. Although several of these methods are no longer commonly practiced today, many streams throughout the United States remain in a degraded condition as a result of mining activities that, in some cases, occurred more than a century ago. Such mining activity frequently resulted in total destruction of the stream corridor. In some cases today, mining operations still disturb most or all of entire watersheds.

Vegetative Clearing

Mining can often remove large areas of vegetation at the mine site, transportation facilities, processing plant, tailings piles, and related activities. Reduced shade can increase water temperatures enough to harm aquatic species.

Loss of cover vegetation, poor-quality water, changes in food availability, disruption of migration patterns, and similar difficulties can have serious effects on terrestrial wildlife. Species composition may change significantly with a shift to more tolerant species. Numbers will likely drop as well. Mining holds few positive benefits for most wildlife species.

Soil Disturbance

Transportation, staging, loading, processing, and similar activities cause extensive changes to soils including loss of topsoils and soil compaction. Direct displacement for construction of facilities reduces the number of productive soil acres in the watershed. Covering of soil by materials such as tailings piles further reduces the acreage of productive soils. These activities decrease infiltration, increase runoff, accelerate erosion, and increase sedimentation.

Figure 3.18: Results of surface mining.
Many streams remain in a degraded condition as a result of mining activities.

Floating dredges and hydraulic mining with high-pressure hoses earlier in the century completely altered streamcourses.

Altered Hydrology

Changes to hydrologic conditions due to mining activity are extensive. Surface mining is, perhaps, the only land use with a greater capacity to change the hydrologic regime of a stream than urbanization. Increased runoff and decreased surface roughness will cause peaks earlier in the hydrograph with steeper rising and falling limbs. Once-perennial streams may become intermittent or ephemeral as baseflow decreases.

Changes in the quantity of water leaving a watershed are directly proportional to the amount of impervious surface or reduced infiltration in a watershed. Loss of topsoils, soil compaction, loss of vegetation, and related actions will decrease infiltration, increase runoff, increase stormflow, and decrease baseflows. Total water leaving the watershed may increase due to reduced in-soil storage.

Stream geomorphology can change dramatically, depending on the mining method used. Floating dredges and hydraulic mining with high-pressure hoses earlier in the century completely altered streamcourses. In many places virtually no trace of the original stream character exists today. Flow may run completely out of view into piles of mine tailings. Once-meandering streams may now be straight, gullied channels. Less extreme mining methods can also significantly alter stream form and function through steepening or lowering the gradient, adding high sediment loads, adding excessive water to the system, or removing water from the system.

Contaminants

Water and soils are contaminated by *acid mine drainage* (AMD) and the materials used in mining. AMD, formed from the oxidation of sulfide minerals like pyrite, is widespread. Many hard rock mines are located in iron sulfide deposits. Upon exposure to water and air, such deposits undergo sulfide oxidation with attendant release of iron, toxic metals (lead, copper, zinc) and excessive acidity. Mercury was often used to separate gold from the ore, therefore, mercury was also lost into streams. Present-day miners using suction dredges often find considerable quantities of mercury still resident in streambeds. Current heap-leaching methods use cyanide to extract gold from low-quality ores. This poses a special risk if operations are not carefully managed.

Toxic runoff or precipitates can kill streamside vegetation or can cause a shift to species more tolerant of mining conditions. This affects habitat required by many species for cover, food, and reproduction.

Aquatic habitat suffers from several factors. Acid mine drainage can coat stream bottoms with iron precipitates, thereby affecting the habitat for bottom-dwelling and feeding organisms. AMD also adds sulfuric acid to the water, killing aquatic life. The low pH alone can be toxic, and most metals exhibit higher solubility and more bioavailability under acidic conditions. Precipitates coating the stream bottom can eliminate places for egg survival. Fish that do hatch may face hostile stream conditions due to poor water quality, loss of cover, and limited food base.

Recreation

The amount of impact caused by recreation depends on soil type, vegetation cover, topography, and intensity of use. Various forms of foot and vehicular traffic associated with recreational activities can damage riparian vegetation and soil structure. All-terrain vehicles, for example, can cause increased erosion and habitat reduction. At locations heavily used by hikers and tourists, reduced infiltration due to soil compaction and subsequent surface runoff can result in increased sediment loading to the stream (Cole and Marion 1988). Widening of the stream channel can occur where hiking trails cross the stream or where intensive use destroys bank vegetation (**Figure 3.19**).

Figure 3.19: Trail sign.
Recreational hiking can cause soil compaction and increased surface runoff.

In areas where the stream can support recreational boating, the system is vulnerable to additional impacts (**Figure 3.20**). Propeller wash and water displacement can disrupt and resuspend bottom sediments, increase bank erosion, and disorient or injure sensitive aquatic species. In addition, waste discharges or accidental spills from boats or loading facilities can contribute pollutants to the system (Natural Research Council 1992).

Both concentrated and dispersed recreational use of stream corridors can cause disturbance and ecological change. Camping, hunting, fishing, boating, and other forms of recreation can cause serious disturbances to bird colonies. Ecological damage primarily results from the need for access for the

Figure 3.20: Recreational boating.
Propeller wash and accidental spills can degrade stream conditions.

recreational user. A pool in the stream might be the attraction for a swimmer or fisherman, whereas a low streambank might provide an access point for boaters. In either case, a trail often develops along the shortest or easiest route to the point of access on the stream. Additional impact may be a function of the mode of access to the stream: motorcycles and horses cause far more damage to vegetation and trails than do pedestrians.

Urbanization

Urbanization in watersheds poses special challenges to the stream restoration practitioner. Recent research has shown that streams in urban watersheds have a character fundamentally different from that of streams in forested, rural, or even agricultural watersheds. The amount of impervious cover in the watershed can be used as an indicator to predict how severe these differences can be. In many regions of the country, as little as 10 percent watershed impervious cover has been linked to stream degradation, with the degradation becoming more severe as impervious cover increases (Schueler 1995).

Impervious cover directly influences urban streams by dramatically increasing surface runoff during storm events (**Figure 3.21**). Depending on the degree of watershed impervious cover,

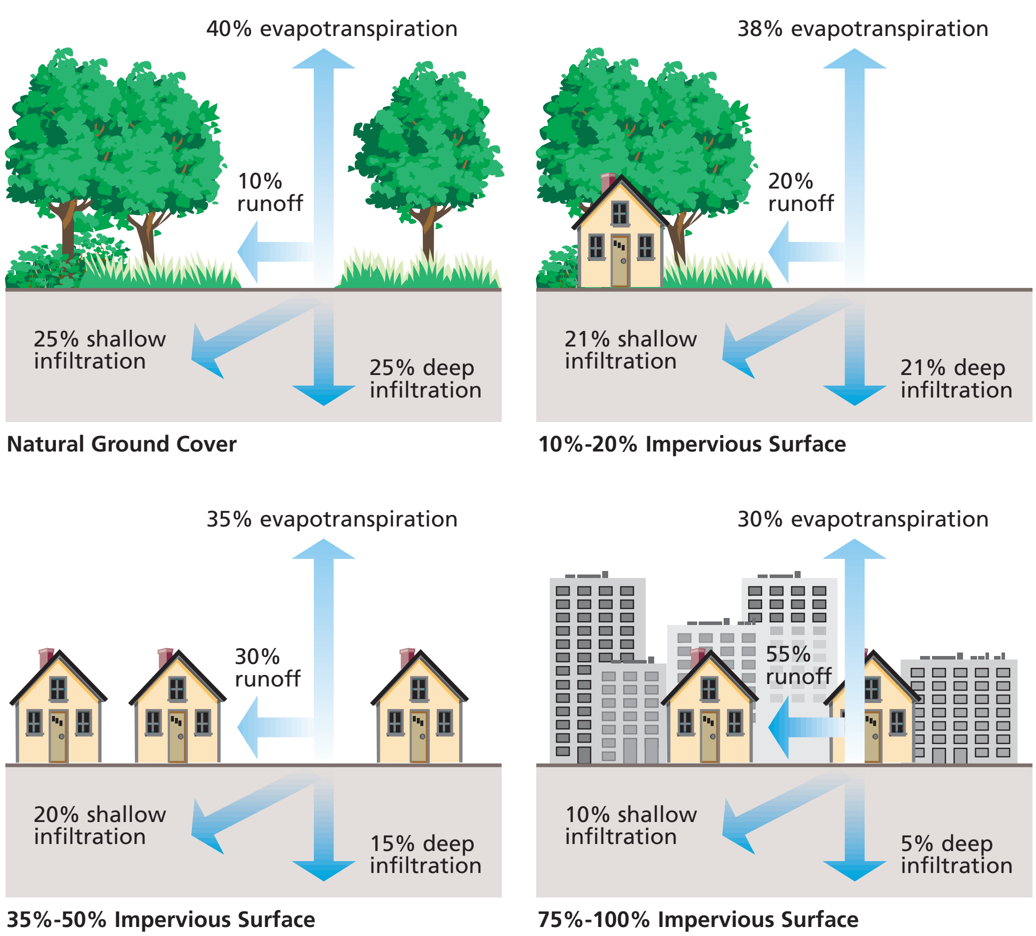


Figure 3.21: Relationship between impervious cover and surface runoff. *Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.*

the annual volume of storm water runoff can increase by 2 to 16 times its predevelopment rate, with proportional reductions in ground water recharge (Schueler 1995).

The unique character of urban streams often requires unique restoration strategies for the stream corridor. For example, the practitioner must seriously consider the degree of upland development that has occurred or is projected to occur. In most projects, it is advisable or even necessary to investigate whether upstream detention or retention can be provided within the watershed to at least partially restore the predevelopment hydrologic regime.

Some of the key changes in urban streams that merit special attention from the stream restoration practitioner are discussed in the following subsections.

Altered Hydrology

The peak discharge associated with the bankfull flow (i.e., the 1.5- to 2-year return storm) increases sharply in magnitude in urban streams. In addition, channels experience more bankfull flood events each year and are exposed to critical erosive velocities for longer intervals (Hollis 1975, Macrae 1996, Booth et al. 1997).

Since impervious cover prevents rainfall from infiltrating into the soil, less flow is available to recharge ground water. Consequently, during extended periods without rainfall, baseflow levels are often reduced in urban streams (Simmons 1982).

Altered Channels

The hydrologic regime that had defined the geometry of the predevelopment stream channel irreversibly changes toward higher flow rates on a more frequent basis. The higher flow events of urban streams are capable of performing more "effective work" in moving sediment than they had done before (Wolman 1964).

The customary response of urban streams is to increase their cross-sectional area to accommodate the higher flows. This is done by streambed downcutting or streambank widening, or a combination of both. Urban stream channels often enlarge their cross-sectional areas by a factor of 2 to 5, depending on the degree of impervious cover in the upland watershed and the age of development (Arnold et al. 1982, Gregory et al. 1992, and Macrae 1996).

Stream channels react to urbanization not only be adjusting their widths and depths, but also by changing their gradients and meanders (Riley, 1998).

Urban stream channels are also extensively modified in an effort to protect adjacent property from streambank erosion or flooding (**Figure 3.22**).

Figure 3.22: Urban stream channel modifications. *Channel armoring often prevent streams from accommodating hydrologic changes that result from urbanization.*

Headwater streams are frequently enclosed within storm drains, while others are channelized, lined, or armored by heavy stone. Another modification unique to urban streams is the installation of sanitary sewers underneath or parallel to the stream channel.

The wetted perimeter of a stream is the proportion of the total cross-sectional area of the channel that is covered by flowing water during dry-weather periods. It is an important indicator of habitat degradation in urban streams. Given that urban streams develop a larger channel cross section at the same time that their baseflow rates decline, it necessarily follows that the wetted perimeter will become smaller. Thus, for many urban streams, this results in a very shallow low-flow channel that wanders across a very wide streambed, often changing its lateral position in response to storms.

Figure 3.23: Water quality in urban streams.
Surface runoff carries numerous pollutants to urban streams, resulting in consistently poor water quality.
Source: C. Zabawa

Sedimentation and Contaminants

The prodigious rate of channel erosion in urban streams, coupled with sediment erosion from active construction sites, increases sediment discharge to urban streams. Researchers have documented that channel erosion constitutes as much as 75 percent the total sediment budget of urban streams (Crawford and Lenat 1989, Trimble 1997). Urban streams also tend to have a higher sediment discharge than nonurban streams, at least during the initial period of active channel enlargement.

The water quality of urban streams during storm events is consistently poor. Urban storm water runoff contains moderate to high concentrations of sediment, carbon, nutrients, trace metals, hydrocarbons, chlorides, and bacteria (Schueler 1987) (**Figure 3.23**). Although considerable debate exists as to whether storm water pollutant concentrations are actually toxic to aquatic organisms, researchers agree that pollutants deposited in streambeds exert undesirable impacts on stream communities.

Habitat and Aquatic Life

Urban streams are routinely scored as having poor instream habitat quality, regardless of the specific metric or method employed. Habitat degradation is often exemplified by loss of pool and riffle structure, embedding of streambed sediments, shallow depths of flow, eroding and unstable banks, and frequent streambed turnover.

Large woody debris (LWD) is an important structural component of many low-order streams systems, creating complex habitat structure and generally making the stream more retentive. In urban streams, the quantity of LWD found in stream channels is reduced due to the loss of riparian forest cover, storm washout, and channel maintenance practices (Booth et al. 1996, May et al. 1997).

Many forms of urban development are linear in nature (e.g., roads, sewers, and pipelines) and cross stream channels. The number of stream crossings increases directly in proportion to impervious cover (May et al. 1997), and many crossings can become partial or total barriers to upstream fish migration, particularly if the streambed erodes below the fixed elevation of a culvert or a pipeline.

The important role that riparian forests play in stream ecology is often diminished in urban watersheds since tree cover is often partially or totally removed along the stream as a consequence of development (May et al. 1997) (**Figure 3.24**). Even when stream buffers are reserved, encroachment often reduces their effective width and native species are supplanted by exotic trees, vines and ground covers.

The impervious surfaces, ponds, and poor riparian cover in urban watersheds can increase mean summer stream temperatures by 2 to 10 degrees Fahrenheit (Galli 1991). Since temperature plays a central role in the rate and timing of biotic and abiotic reactions in stream, such increases have an adverse impact on streams. In some regions, summer stream warming can irreversibly shift a cold-water stream to a cool-water or even warm-water stream, with deleterious effects on salmonoids and other temperature-sensitive organisms.

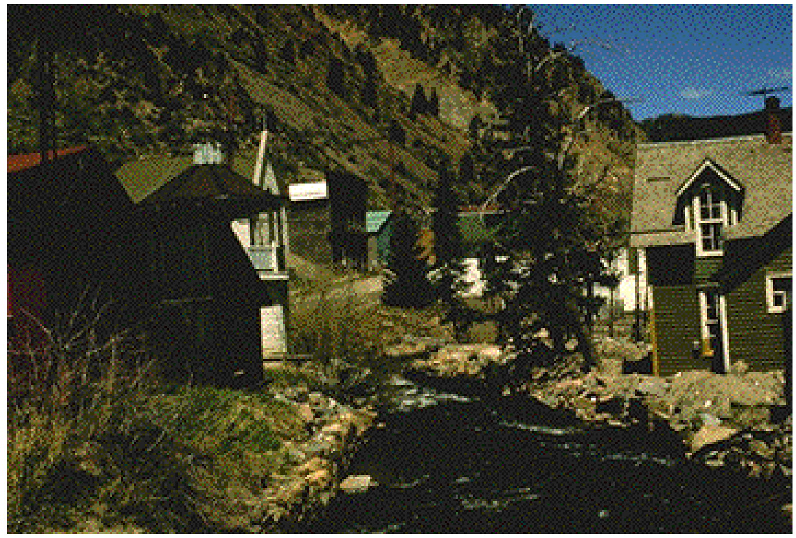


Figure 3.24: Stream corridor encroachment. *Stream ecology is disturbed when riparian forests are removed for development.*

Urban streams are typified by fair to poor fish and macroinvertebrate diversity, even at relatively low levels of watershed impervious cover or population density (Schueler 1995, Shaver et al. 1995, Couch 1997, May et al. 1997). The ability to restore predevelopment fish assemblages or aquatic diversity is constrained by a host of factors—irreversible changes in carbon supply, temperature, hydrology, lack of instream habitat structure, and barriers that limit natural recolonization.

Summary of Potential Effects of Land Use Activities

Table 3.3 presents a summary of the disturbance activities associated with major land uses and their potential for changing stream corridor functions. Many of the potential effects of disturbance are cumulative or synergistic. Restoration might not remove all disturbance factors; however, addressing one or two disturbance activities can dramatically reduce the impact of those remaining. Simple changes in management, such as the use of conservation buffer strips in cropland or managed livestock access to riparian areas, can substantially overcome undesired cumulative effects or synergistic interactions.

Table 3.3: Potential effects of major land use activities

Potential Effects	Disturbance Activities: Vegetative Clearing	Channelization	Streambank Armoring	Streambed Disturbance	Withdrawal of Water	Dams	Levees	Soil Exposure or Compaction	Irrigation and Drainage	Contaminants	Hard Surfacing	Overgrazing	Roads and Railroads	Trails	Exotic Species	Utility Crossings	Reduction of Floodplain	Dredging for Mineral Extract.	Land Grading	Bridges	Woody Debris Removal	Piped Discharge/Cont.Outlets
homogenization of landscape elements	■	■	□	□	□	□	□	□	■	□	□	■	□	□	■	□	■	■	■	□	□	□
point source pollution	□	□	□	□	□	■	□	□	□	■	■	■	■	□	□	■	□	■	□	□	□	■
nonpoint source pollution	■	■	□	■	□	□	■	□	■	■	■	■	■	■	□	■	□	■	■	□	■	■
dense compacted soil	■	□	■	□	□	■	■	■	□	□	■	■	■	■	□	■	■	■	■	□	□	□
increased upland surface runoff	■	□	□	□	□	□	□	■	■	□	■	■	■	■	□	□	□	□	■	□	□	□
increased sheetflow w/surface erosion rill and gully flow	■	□	□	□	□	□	□	■	■	□	■	■	■	■	□	□	□	□	■	□	□	□
increased levels of fine sediment and contaminants in stream corridor	■	■	□	■	□	■	■	■	■	■	■	■	■	■	□	■	■	■	■	■	■	■
increased soil salinity	□	□	□	□	■	□	□	□	■	■	■	□	■	□	□	□	□	□	□	□	□	□
increased peak flood elevation	■	■	□	□	□	■	■	■	■	□	■	■	■	□	□	□	■	□	□	□	□	■
increased flood energy	■	■	■	■	□	□	■	■	■	□	■	■	■	□	□	□	■	□	□	□	■	■
decreased infiltration of surface runoff	■	□	■	□	□	□	□	■	■	□	■	■	■	■	□	□	□	□	■	□	□	■
decreased interflow and subsurface flow	■	■	■	□	□	□	□	■	□	■	□	□	□	□	□	□	□	□	■	□	□	■
reduced groundwater recharge and aquifer volumes	■	□	□	□	■	■	■	■	■	□	■	■	■	□	□	□	■	■	□	□	■	■
increased depth to groundwater	■	■	□	□	■	■	■	■	■	□	■	■	■	□	□	□	■	■	■	□	□	□
decreased groundwater inflow to stream	■	■	■	□	■	□	■	■	■	□	■	■	■	□	□	□	■	■	■	□	□	■
increased flow velocities	■	■	■	■	□	■	■	■	■	□	■	■	■	□	□	□	■	■	■	□	■	■
reduced stream meander	□	■	■	■	□	■	■	□	□	□	■	□	□	□	□	□	■	□	■	□	■	■
increased or decreased stream stability	■	■	■	■	■	■	■	■	□	□	■	■	■	□	□	□	■	■	■	■	■	■
increased stream migration	■	□	□	■	□	□	□	■	□	□	■	■	■	□	□	□	■	■	□	□	■	■
channel widening and downcutting	■	■	■	■	■	■	■	□	□	□	■	■	■	□	□	□	■	■	□	■	■	■
increased stream gradient and reduced energy dissipation	□	■	■	■	■	■	■	□	□	□	□	□	□	□	□	□	■	■	□	□	■	■
increased or decreased flow frequency	■	□	□	□	■	■	■	■	■	□	■	■	■	□	□	□	■	□	■	□	□	■
reduced flow duration	■	■	■	■	■	□	■	■	■	□	■	■	■	□	□	□	■	□	□	□	■	■
decreased capacity of floodplain and upland to accumulate, store and filter materials and energy	■	□	□	□	□	□	■	■	■	■	■	■	■	■	□	□	■	■	■	□	■	■
increased levels of sediment and contaminants reaching stream	■	■	■	■	□	□	□	□	■	■	■	■	■	□	□	■	□	■	■	■	■	■
decreased capacity of stream to accumulate and store or filter materials and energy	□	■	■	■	□	□	■	□	□	■	□	□	□	□	□	□	□	■	□	□	■	■
reduced stream capacity to assimilate nutrients/pesticides	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	■	■	□	□	■	■
confined stream channel w/little opportunity for habitat development	□	■	■	■	□	□	■	□	□	□	□	□	□	□	□	□	■	□	□	□	□	□

■ Activity has potential for direct impact. □ Activity has potential for indirect impact.

Table 3.3: Potential effects of major land use activities *(continued)*

Potential Effects	Vegetative Clearing	Channelization	Streambank Armoring	Streambed Disturbance	Withdrawal of Water	Dams	Levees	Soil Exposure or Compaction	Irrigation and Drainage	Contaminants	Hard Surfacing	Overgrazing	Roads and Railroads	Trails	Exotic Species	Utility Crossings	Reduction of Floodplain	Dredging for Mineral Extract.	Land Grading	Bridges	Woody Debris Removal	Piped Discharge/Cont.Outlets
increased streambank erosion and channel scour	■	■	□	■	□	■	■	■	□	□	□	■	□	□	□	□	□	■	□	□	■	■
increased bank failure	■	■	□	□	■	■	■	■	□	□	□	■	□	□	□	□	□	■	□	□	■	■
loss of instream organic matter and related decomposition	■	■	■	■	□	■	■	□	□	□	□	■	□	□	□	□	■	■	□	□	■	□
increased instream sediment, salinity, and turbidity	■	■	□	■	□	■	■	□	■	■	■	■	■	■	□	■	■	■	■	□	■	■
increased instream nutrient enrichment, siltation, and contaminants leading to eutrophication	■	□	□	■	□	■	■	■	■	■	■	■	■	□	□	■	■	■	□	□	■	■
highly fragmented stream corridor with reduced linear distribution of habitat and edge effect	■	■	■	□	■	■	□	□	□	□	■	■	□	□	□	□	■	■	■	■	■	□
loss of edge and interior habitat	■	■	■	■	□	□	■	□	□	□	■	■	■	□	■	□	■	■	■	□	■	□
decreased connectivity and width within the corridor and to associated ecosystems	■	■	■	■	□	■	■	□	□	□	■	■	■	■	■	■	■	■	■	■	□	□
decreased movement of flora and faunal species for seasonal migration, dispersal, and population	■	■	■	■	■	■	■	□	□	□	■	■	■	■	■	■	■	■	■	■	□	□
increase of opportunistic species, predators, and parasites	■	■	■	□	□	■	■	□	□	■	□	■	□	■	■	■	□	□	□	□	■	■
increased exposure to solar radiation, weather, and temperature extremes	■	■	■	■	■	□	■	■	□	□	■	■	■	■	□	■	■	■	■	□	■	□
magnified temperature and moisture extremes throughout the corridor	■	□	□	□	□	□	■	■	□	□	■	■	□	□	□	□	□	□	□	□	□	□
loss of riparian vegetation	■	■	■	■	■	■	■	■	□	□	□	■	■	■	■	■	■	■	□	■	■	□
decreased source of instream shade, detritus, food, and cover	■	■	■	■	■	□	■	□	□	□	□	□	□	□	□	□	□	■	□	□	■	□
loss of vegetative composition, structure, and height diversity	■	■	■	□	■	□	■	□	■	□	■	■	■	□	■	□	■	■	□	□	□	□
increased water temperature	■	■	■	■	■	■	■	□	□	□	■	■	□	□	□	□	■	■	□	□	■	□
impaired aquatic habitat diversity	■	■	■	■	■	■	■	□	■	■	■	■	□	□	■	□	■	■	□	□	■	■
reduced invertebrate population in stream	■	■	■	■	■	■	■	□	■	■	■	■	□	□	■	□	■	■	□	□	■	■
loss of associated wetland function including water storage, sediment trapping, recharge, and habitat	□	■	□	■	■	■	■	□	■	□	■	■	■	□	■	□	■	■	■	□	□	□
reduced instream oxygen concentration	■	■	■	■	■	■	■	□	□	□	■	■	□	□	□	□	■	■	□	□	■	■
invasion of exotic species	■	■	■	■	■	□	■	□	□	□	□	■	□	□	■	□	■	□	□	□	□	■
reduced gene pool of native species for dispersal and colonization	■	■	■	■	■	□	■	□	□	□	□	■	□	□	■	□	■	□	□	□	■	□
reduced species diversity and biomass	■	■	■	■	■	□	■	■	■	□	■	■	□	□	■	□	■	□	□	□	■	□

Disturbance Activities

■ Activity has potential for direct impact. □ Activity has potential for indirect impact.